



$$\frac{\Delta P}{L} = f(P, \mu, \nu_m)$$

$$\frac{\Delta P}{L} = f(P, \mu, D, \nu)$$

Buckingham

$$M, L, T$$

$$5 - 3 = 2$$

$$[D] = L$$

$$[\mu] = \frac{M}{L \cdot T}$$

$$\pi_2 = f(\pi_1)$$

$$[\nu] = L/T$$

$$[P] = M/L^3$$

$$\left[\frac{\Delta P}{L}\right] = \frac{M}{L^2 T^2}$$

$$\pi_1 = \mu \cdot P^\alpha \cdot \nu^\beta \cdot D^\delta = M^0 L^0 T^0$$

$$\left[\frac{M}{L T}\right] \left[\frac{M}{L^3}\right]^\alpha \left[\frac{L}{T}\right]^\beta [L]^\delta = M^0 L^0 T^0$$

$$M^{1+\alpha} = M^0 \Rightarrow \alpha = -1$$

$$T^{-1-\beta} = T^0 \Rightarrow \beta = -1$$

$$L^{-1-3\alpha+\beta+\delta} = L^0 \Rightarrow \delta = -1$$

$$\Rightarrow \pi_1 = \frac{\mu}{\rho \nu D} \Rightarrow \pi_1 = \frac{\rho \nu D}{\mu} = Re$$

por convenção

$$\pi_2 = \frac{\Delta P}{L} \frac{D}{\frac{1}{2} \rho \nu_m^2} = f$$

$$f = f(Re)$$

$$f = \frac{C}{Re}$$

$$Re = 2100$$

$$f = C Re^n$$

$$n = \begin{cases} -0.2 \\ -0.25 \end{cases}$$

laminar

transição

turbulento

$$v_z(r) = \left(-\frac{dp}{dz}\right) \frac{R^2}{4\mu} \left(1 - \left(\frac{r}{R}\right)^2\right)$$

$$f = \frac{64}{Re}$$